

# An empirical investigation into the usage of a live debugger

Master Thesis

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# Problem



Applications are complex;  
debugging is difficult

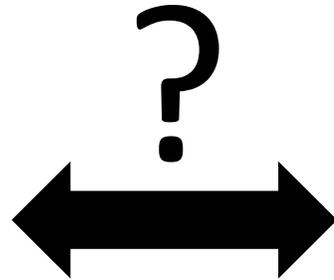


Using the debugger in an efficient way  
is often not an easy task



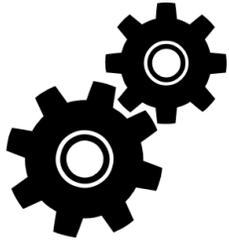
How to improve the debugger?

# How do developers use the debugger?

A screenshot of the ZeroDivide debugger interface. The window title is "ZeroDivide" and it has a "Bytecode" dropdown menu in the top right corner. The interface is divided into three main sections: "Stack", "Source", and "Variables".  
**Stack:** Shows a list of stack frames. The top frame is "SmallInteger /". Below it are "UndefinedObject Dolt", "OpalCompiler evaluate", "RubSmalltalkEditor evaluate:andDo:", "RubSmalltalkEditor highlightEvaluateAndDo:", and "GLMMorphicPharoScriptRenderer(GLMMor actOnHighlightAndEvaluate: [ textMorph textArea editor highlightEvaluateAndDo: ann action. textMorph shoutStyler style: textMorpl".  
**Source:** Shows the source code for the "ZeroDivide" class. The code includes a comment describing the primitive division operation, followed by implementation logic for the "/" method. The current line of execution is highlighted in blue: "aNumber isZero ifTrue: [^(ZeroDivide dividend: self) signal].".  
**Variables:** A table showing the current state of variables.

Type	Variable	Value
implicit	self	1
parameter	aNumber	0
implicit	thisContext	SmallInteger>>/
implicit	stack top	0

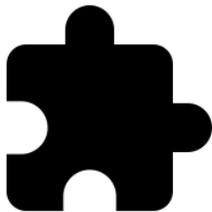
# Research Questions



*RQ1. Debugging Strategies*



*RQ2. Domain-specific information*



*RQ3. Usage of extensions*

# Experiment Setup

## **Group 1**

- 5 participants
- can use any tools

## **Group 2**

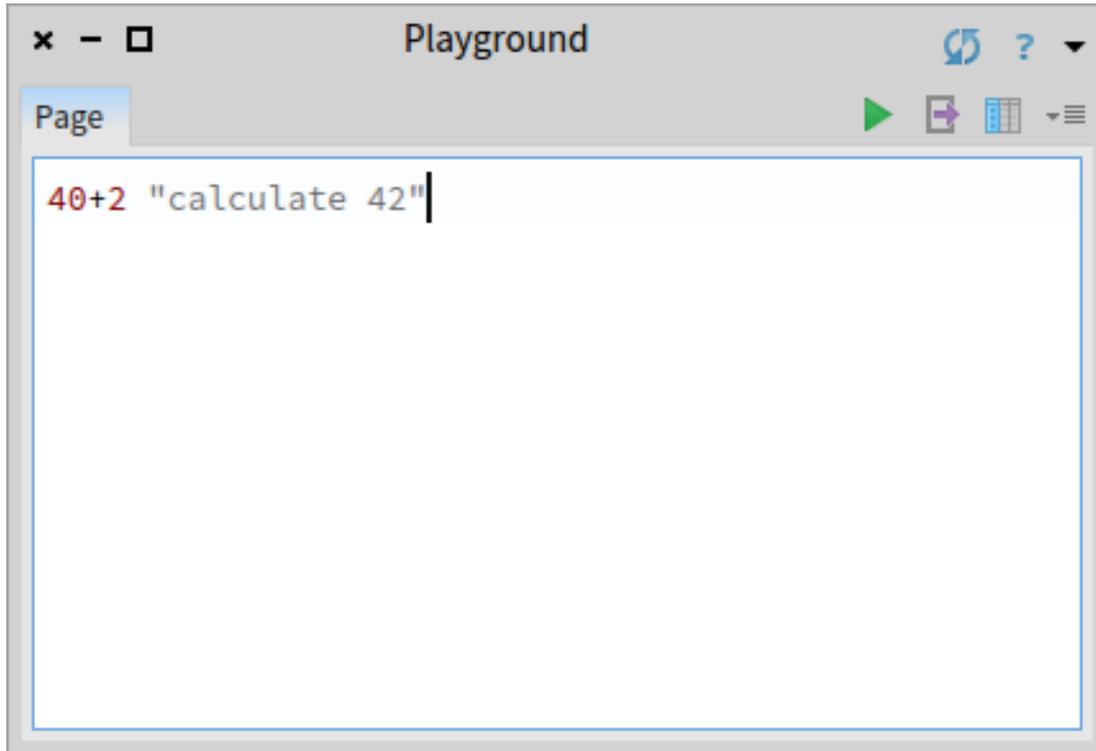
- 5 participants
- can use any tools  
+ domain-specific extensions

Participants randomly selected

∅ programming experience: 10 years

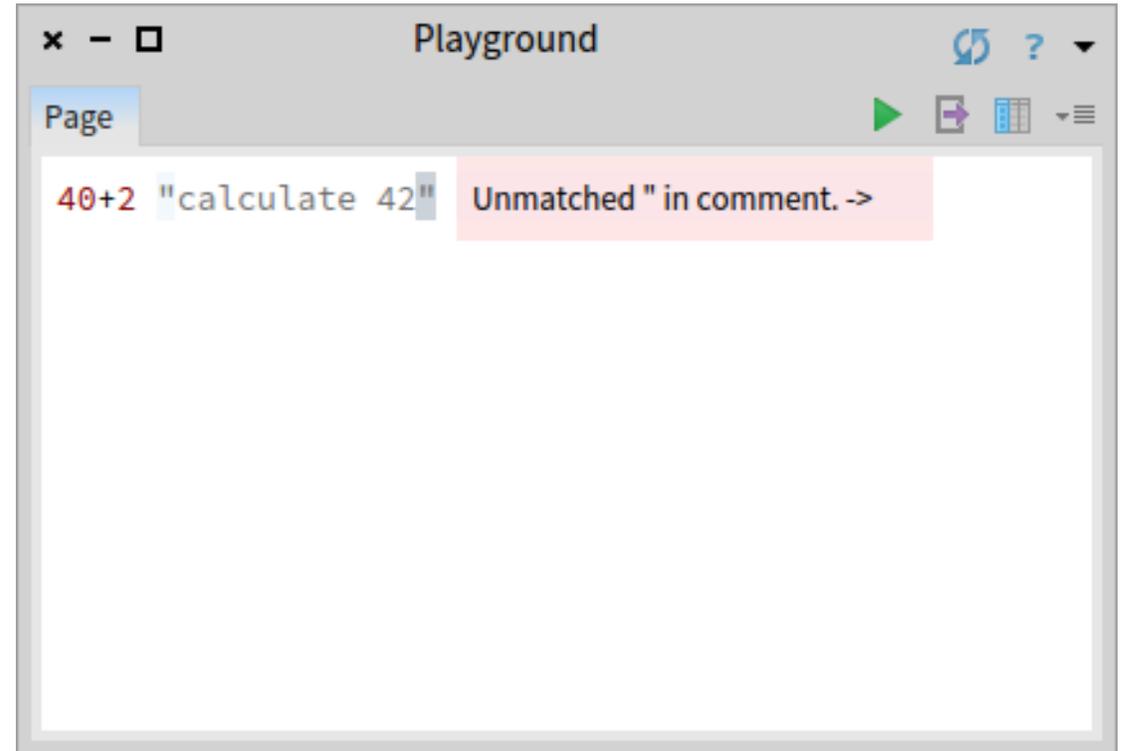
∅ experience with Pharo: 4.5 years

# Experiment: Solve a bug



Playground

```
40+2 "calculate 42"
```



Playground

```
40+2 "calculate 42" Unmatched " in comment. ->
```

Bug in *Rubric* – default text editor in Pharo

# Optimal path

```
evaluateSelectionAndDo: aBlock
```

```
self lineSelectAndEmptyCheck: [^ ''].
```

```
^ self
```

```
evaluate: self selectionForDoitAsStream  
andDo: aBlock
```

testExecutionWithComment

Test

GLMRubricSmalltalkCodePresentation>>#evaluateSelectionAndDo:

deliver:

Announcement

actOnEvaluateSelection:

RubSmalltalkEditor>>#evaluateSelectionAndDo: Evaluation

lineSelectAndEmptyCheck:

selectLine

Line  
selection

computeSelectionIntervalForCurrentLine

# Code of the faulty method

## computeSelectionIntervalForCurrentLine

```
| i left right s |  
s := self string.  
i := s encompassParagraph: self selectionInterval.  
left := i first.  
right := i last.  
[ left <= right and: [ (s at: left) = $" or: [(s at: left) isSeparator] ] ]  
  whileTrue: [ left := left + 1 ].  
[ left <= right and: [ (s at: right) = $" or: [(s at: right) isSeparator] ] ]  
  whileTrue: [ right := right - 1 ].  
^ left to: right
```

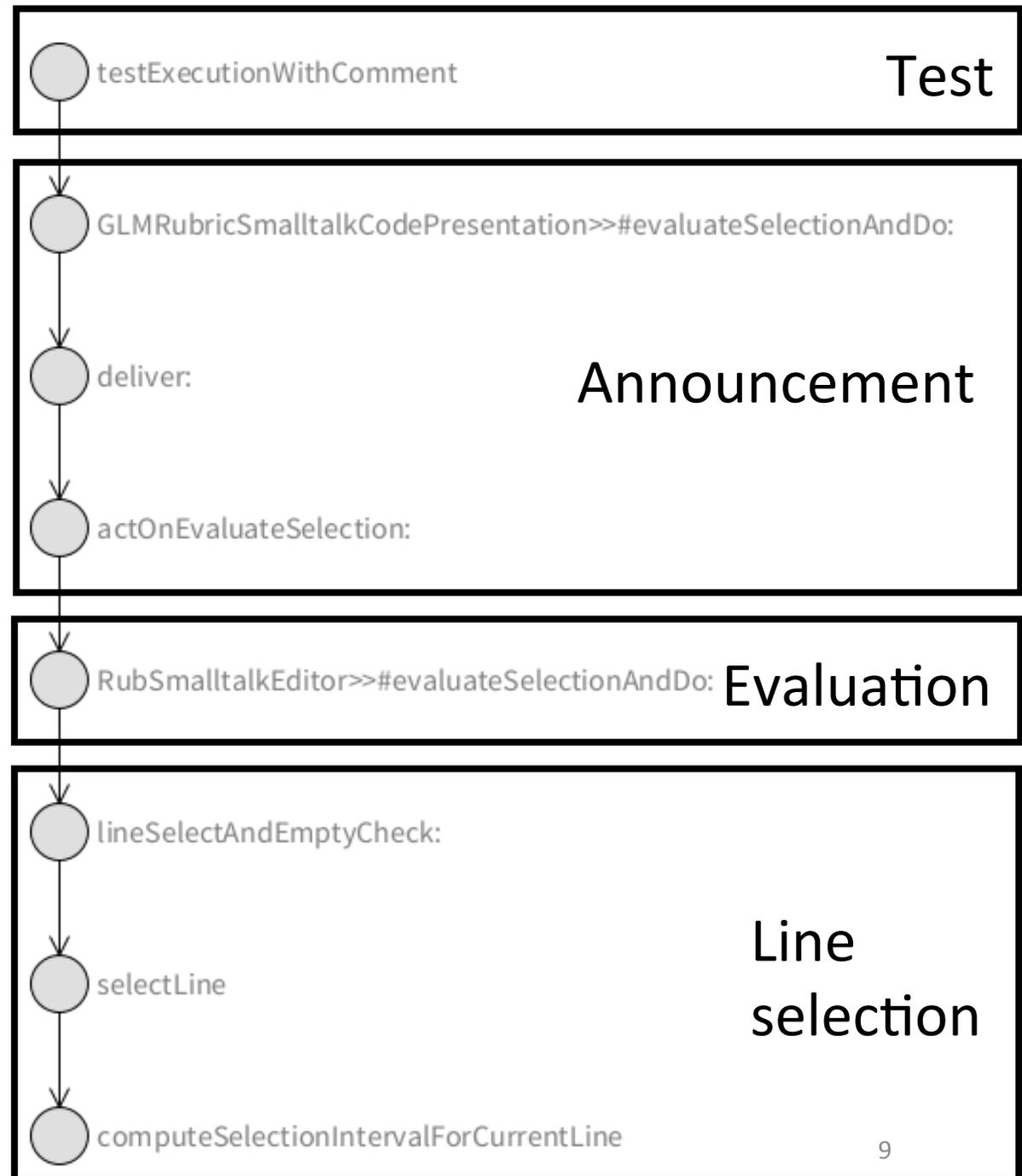
40+2 "calculate 42"

"40+2"

# Optimal path

```
evaluateSelectionAndDo: aBlock
```

```
self announce: (GLMEvaluateSelection new  
  action: aBlock;  
  makeSynchronous)
```



# Domain-specific extensions: Announcements

The screenshot shows the Ruby IDE's 'Halt' window. The title bar includes 'Halt' and 'Announcement Bytecode'. The 'Stack' panel shows the following frames from top to bottom:

- SubscriptionRegistry deliver:to:startingAt:
- SubscriptionRegistry deliver:to:
- SubscriptionRegistry deliver:
- Announcer announce:
- RubEditingArea(Morph) doAnnounce:

The 'Source' panel is set to 'Active subscriptions' and displays a table:

Announcement Type	Action
MorphGotFocus	MessageSend(#whenTextAreaGotFocus: -> a RubFindReplaceService)
<b>MorphGotFocus</b>	<b>MessageSend(#whenGotFocus: -&gt; a RubCursor(755026688))</b>
MorphGotFocus	MessageSend(#whenGotFocus: -> a RubScrolledTextMorph(616525824))
MorphGotFocus	MessageSend(#whenTextAreaGotFocus: -> a RubPrimarySelectionMorph)

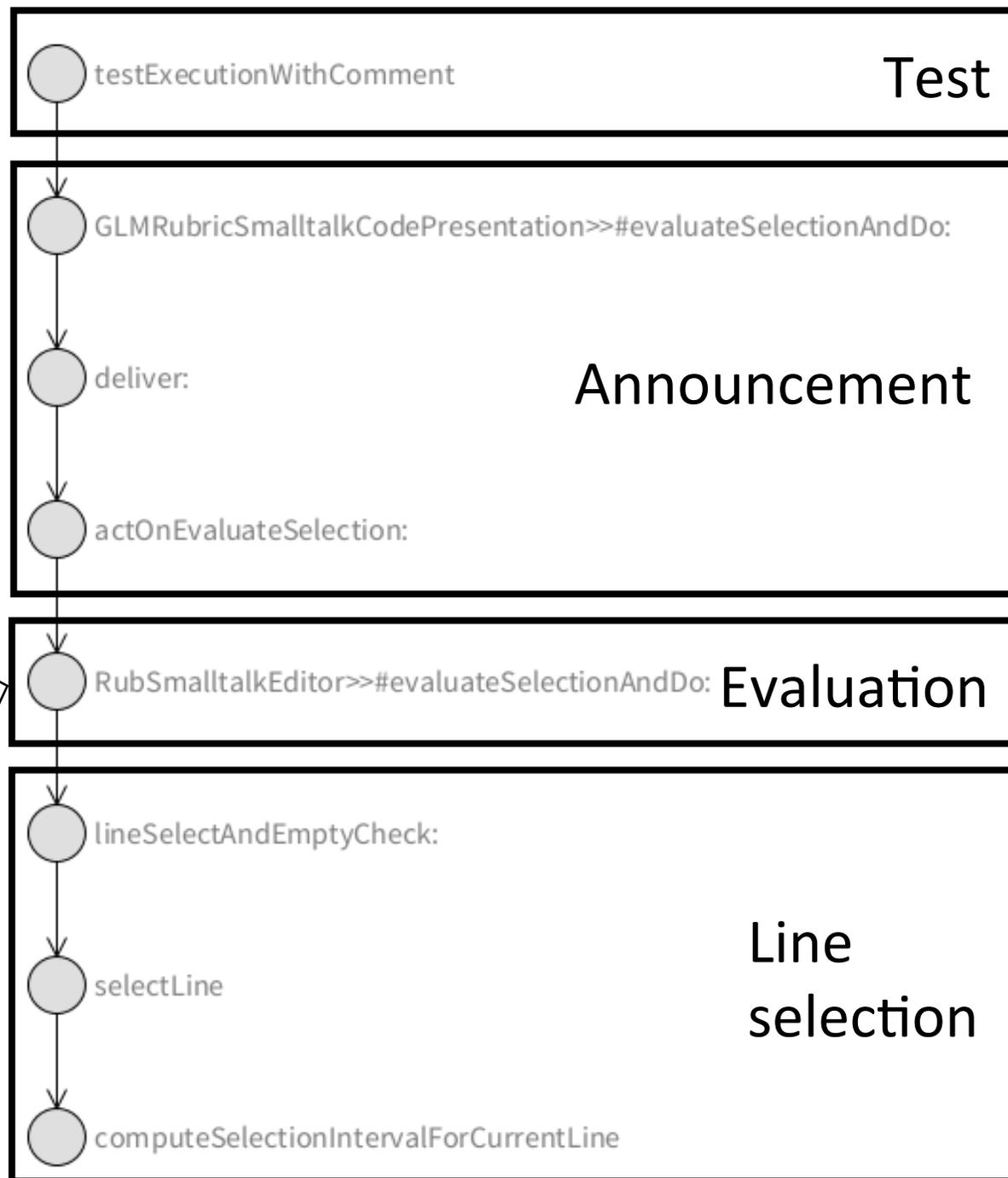
A context menu is open over the selected row, showing options: 'Explore Ctrl + I', 'Browse Ctrl + B', and 'Run to here'.

The 'Variables' panel at the bottom shows the following variables:

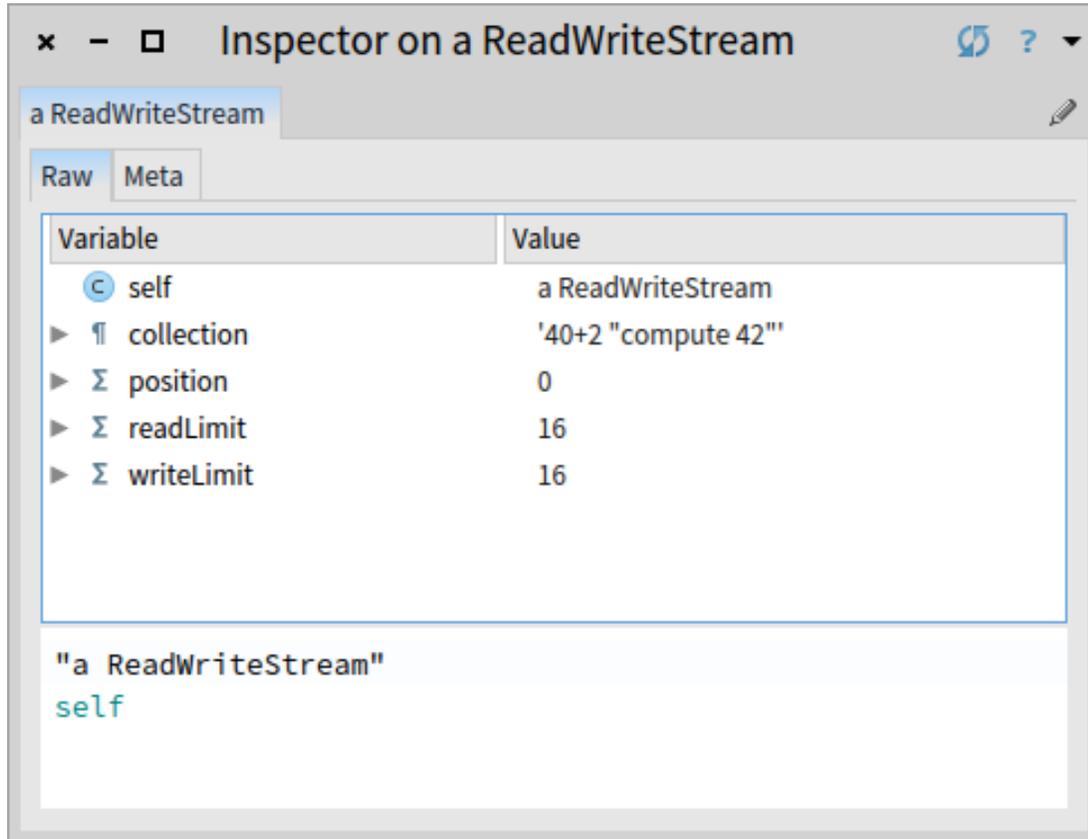
Type	Variable	Value
implicit	self	a SubscriptionRegistry
parameter	anAnnouncement	a MorphGotFocus
temp	index	2
attribute	monitor	a Semaphore()

# Optimal path

```
evaluateSelectionAndDo: aBlock  
self lineSelectAndEmptyCheck: [^ ``].  
^ self  
  evaluate: self selectionForDoitAsStream  
  andDo: aBlock
```



# Domain-specific extensions: Stream



Inspector on a ReadWriteStream

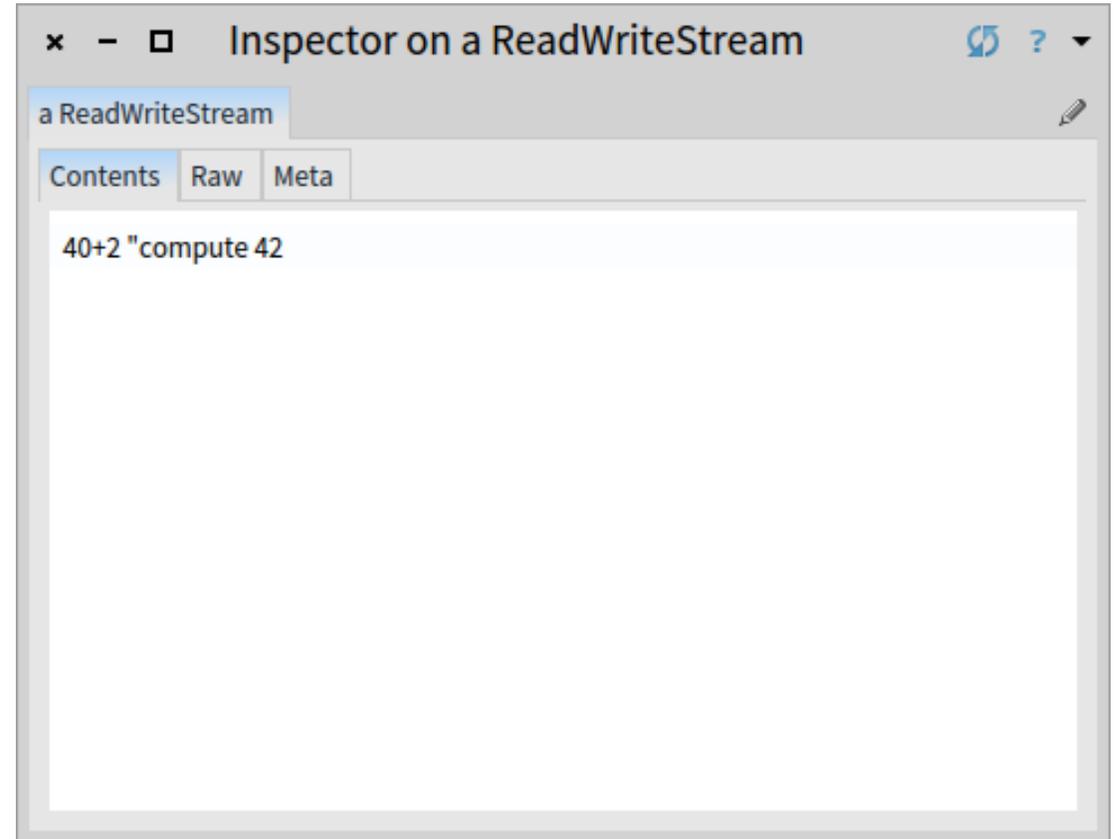
a ReadWriteStream

Raw Meta

Variable	Value
self	a ReadWriteStream
collection	'40+2 "compute 42"'
position	0
readLimit	16
writeLimit	16

"a ReadWriteStream"  
self

Group 1



Inspector on a ReadWriteStream

a ReadWriteStream

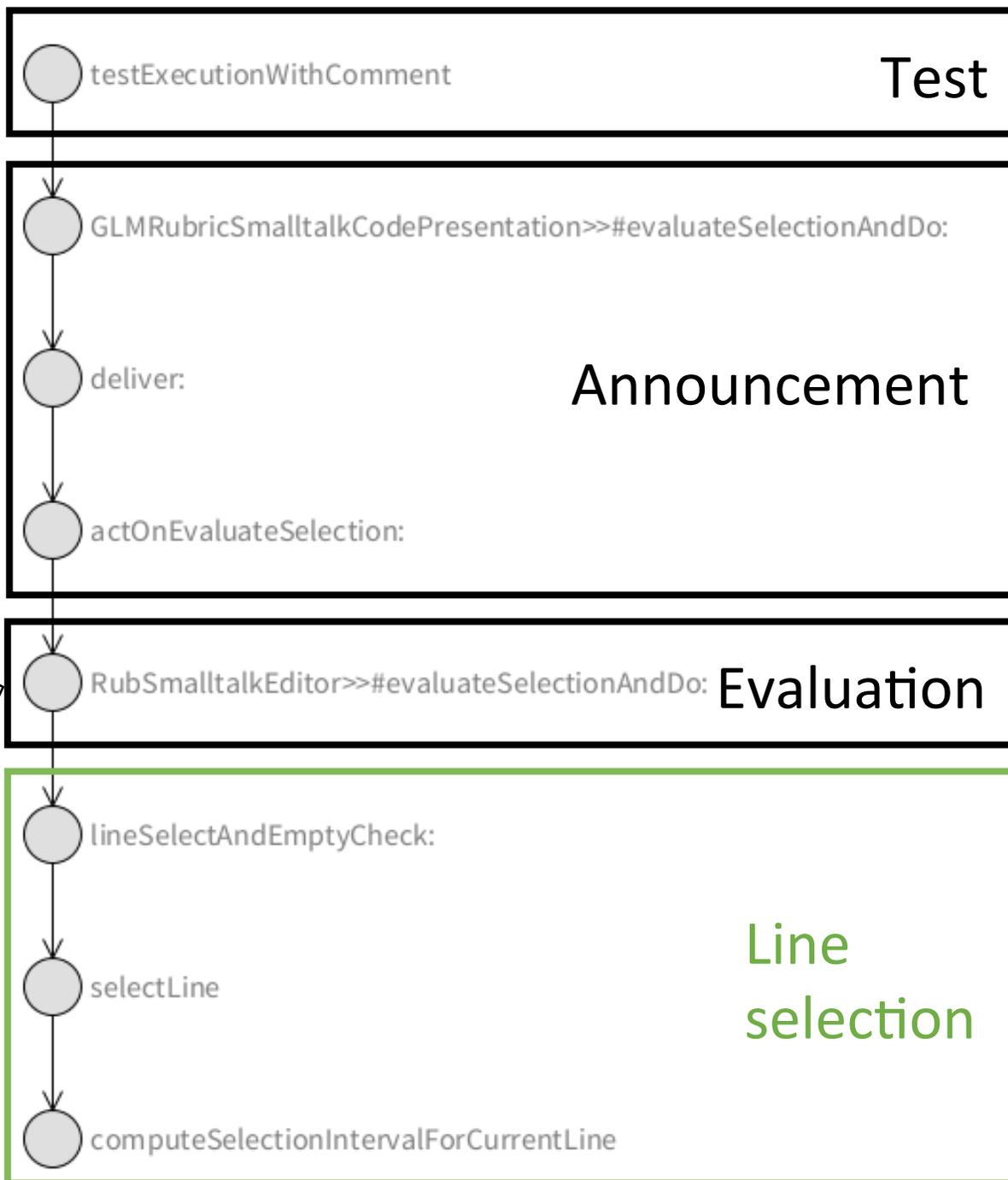
Contents Raw Meta

40+2 "compute 42"

Group 2

# Optimal path

```
evaluateSelectionAndDo: aBlock  
self lineSelectAndEmptyCheck: [^ ``].  
^ self  
  evaluate: self selectionForDoitAsStream  
  andDo: aBlock
```

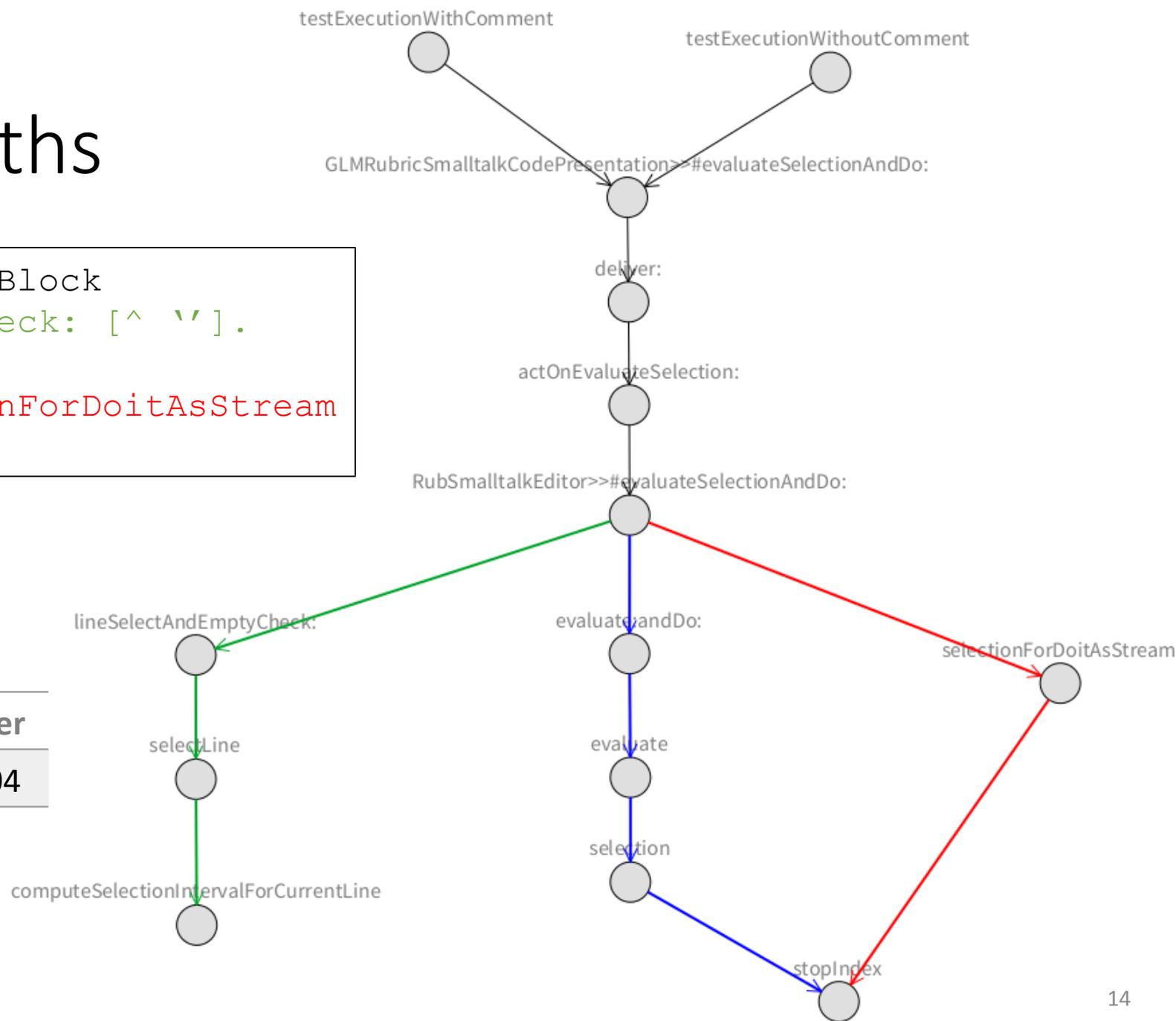


# Navigation Paths

```

evaluateSelectionAndDo: aBlock
self lineSelectAndEmptyCheck: [^ ``].
^ self
  evaluate: self selectionForDoitAsStream
  andDo: aBlock
    
```

Path 0	Path 1	Path 2	Path 3	Other
13:28	05:45	09:19	01:34	02:04



	Group	Realistic?	Difficulty	Duration	Score
P1	1	agree	difficult	40:00	C
P2	1	strongly agree	neutral	23:20	A
P3	2	agree	difficult	40:54	F
P4	2	agree	difficult	45:18	B
P5	2	strongly agree	easy	30:36	A
P6	1	agree	easy	34:34	B
P7	1	agree	difficult	39:41	B
P8	1	strongly agree	difficult	48:30	B
P9	2	agree	neutral	25:17	B
P10	2	strongly agree	difficult	52:44	B

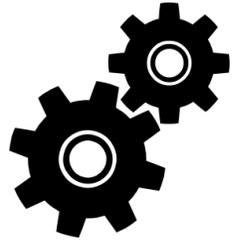
**A.** Participant solved the bug

**B.** Participant discovered that there was a problem in computing the selection

**C.** Participant successfully navigated the propagation of the announcement, but made no other progress

**F.** Participant made no real progress towards solving the bug and was unable to navigate the propagation of the announcement

# RQ1. Debugging Strategies



Behavior-driven exploration

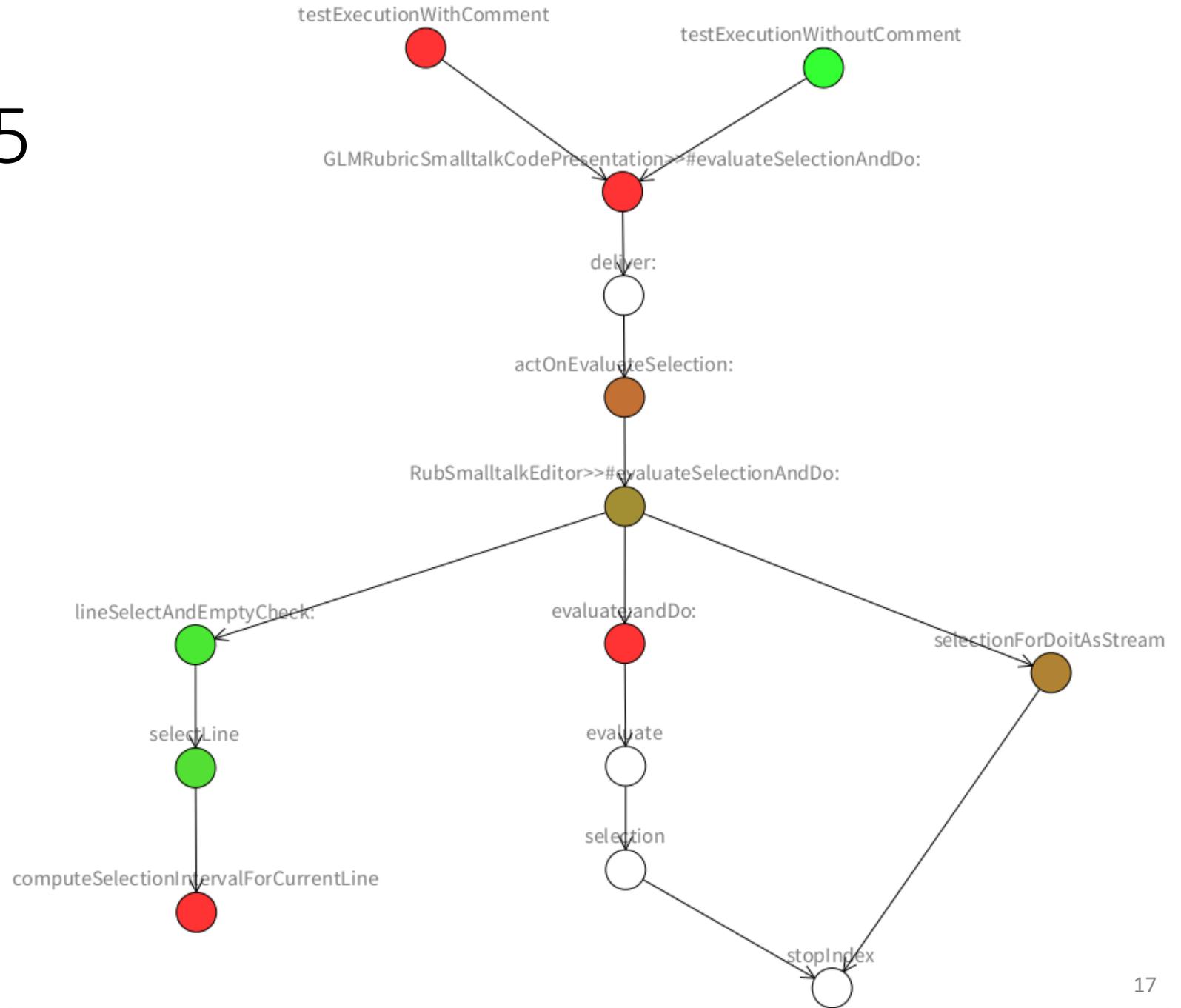


In-depth path exploration

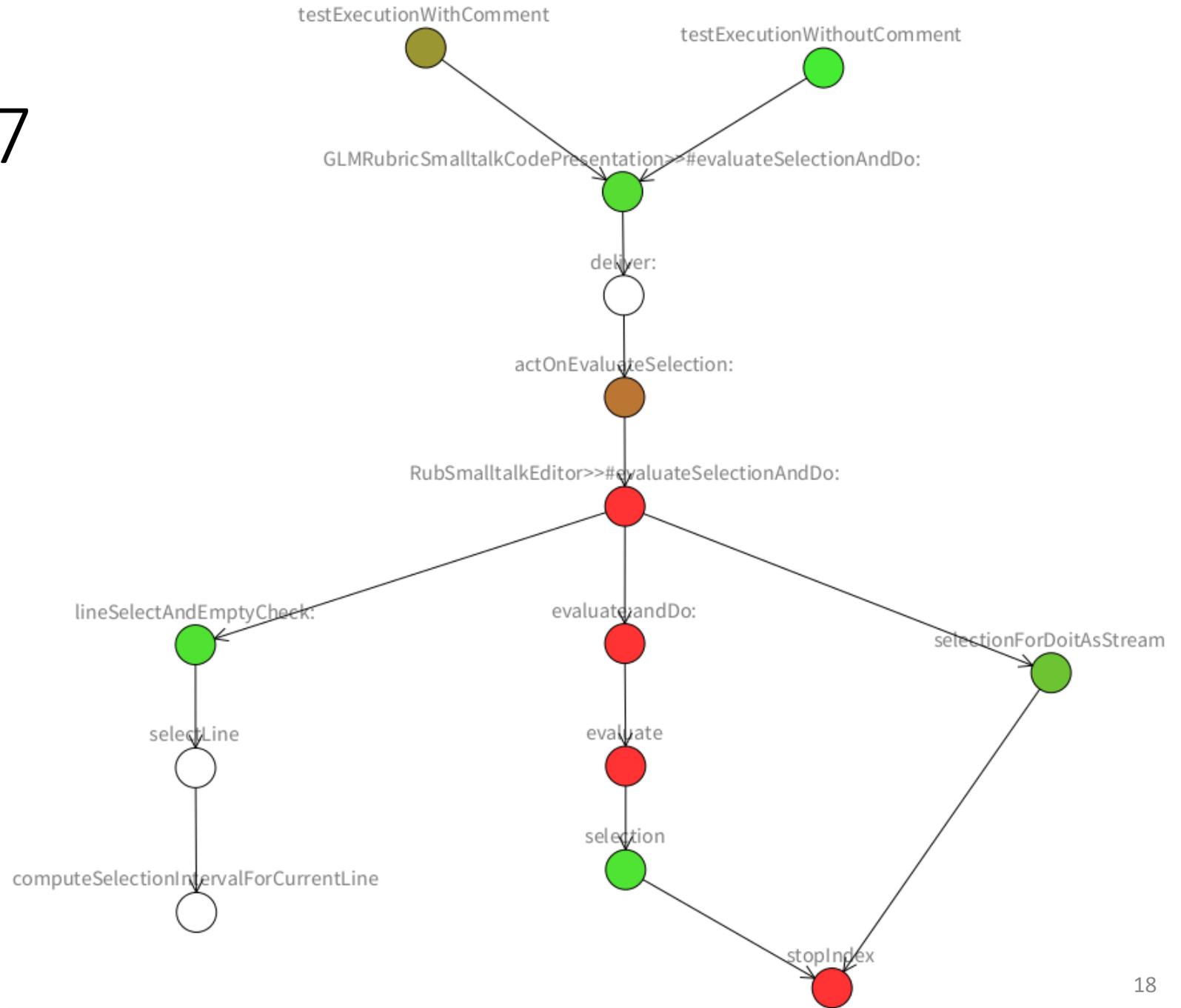


Code-driven exploration

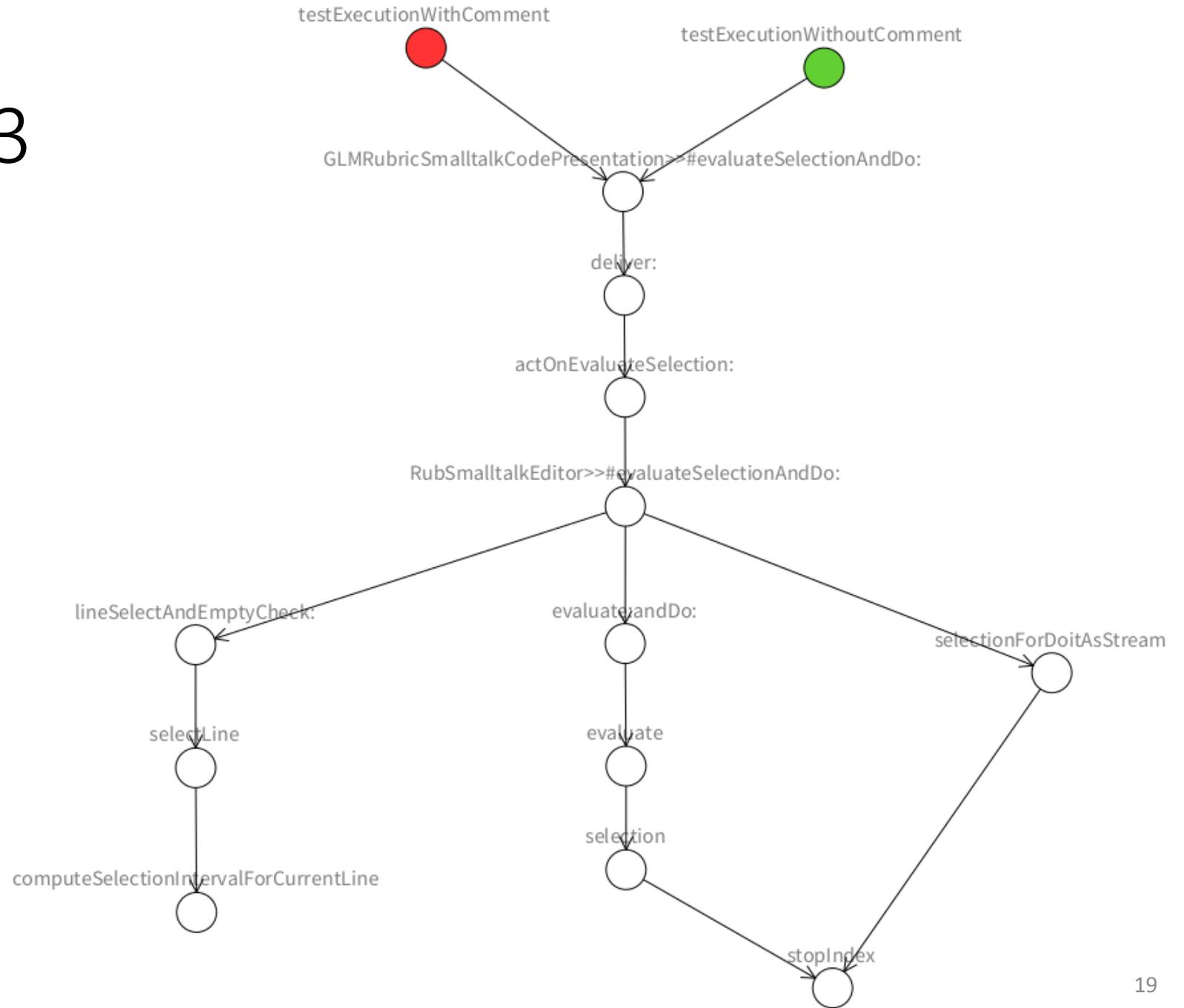
# Navigation P5



# Navigation P7



# Navigation P3



# RQ2. Usage of domain-specific information: Announcements

TestFailure: Got nil instead of 42. Bytecode GT

Stack ▶ Proceed 🔄 Restart 🔍 Into 🔍 Over 🔍 Through

- GLMPharoScriptPresentation(GLMLoggedObject) announce:
- GLMPharoScriptPresentation(GLMRubricSmalltalkCode evaluateSelectionAndDo:
- GTPlaygroundBasicTest testExecutionWithComment
- GTPlaygroundBasicTest(TestCase) performTest
- GTPlaygroundBasicTest(TestCase) runCase [ self setUp. self performTest ]

Source All subscriptions Active subscriptions SetUp TearDown 🔍 Where is? 📄 Browse

```
announce: anAnnouncement
  self logger logAnnouncement: anAnnouncement from: self.
  super announce: anAnnouncement
```

Diff (actual vs. expected) Objects (actual vs. expected) Inspector ?

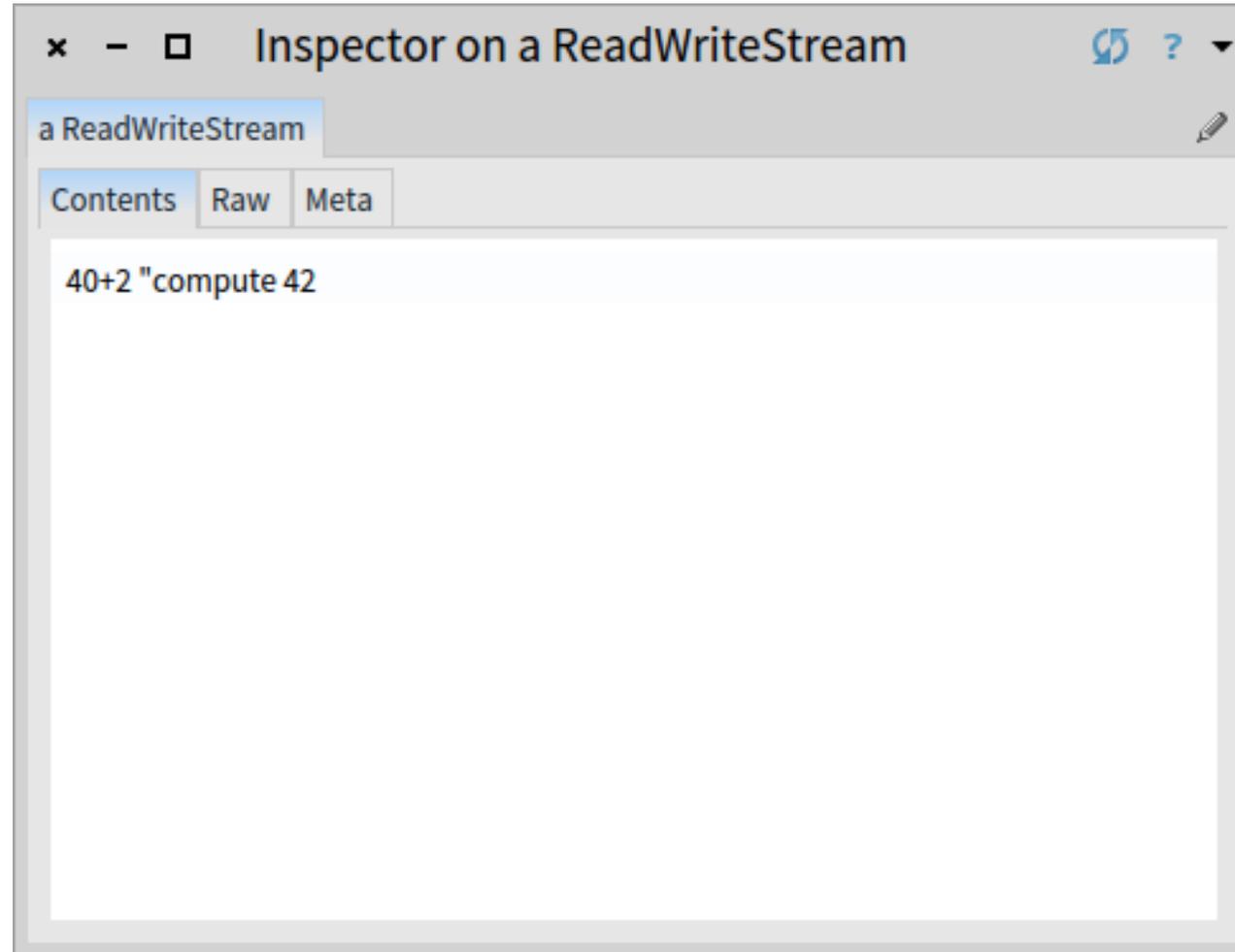
Pretty print

nil	42
-----	----

## RQ2. Usage of domain-specific information: Announcements

	Group	Time	Method	Experience with announcements
P1	1	16:58	Checking action of announcement	Not at all
P2	1	03:03	Stepping through the code using debugger	Extremely knowledgeable
P3	2	-	Did not find the method	Slightly knowledgeable
P4	2	04:35	Checking action of announcement & extension	Not at all
P5	2	05:09	Checking event registration	Extremely knowledgeable
P6	1	06:04	Skipped by searching for error message	Slightly knowledgeable
P7	1	01:58	Checking event registration	Extremely knowledgeable
P8	1	06:50	Checking action of announcement	Moderately knowledgeable
P9	2	03:54	Checking event registration	Somewhat knowledgeable
P10	2	16:12	Checking action of announcement	Somewhat knowledgeable

# RQ2. Usage of domain-specific information: Stream



# RQ2. Usage of domain-specific information: Stream

	Group	Time	Method
P1	1	-	not checked at all
P2	1	01:29	checked contents manually using method <code>#contents</code>
P3	2	-	not checked at all
P4	2	00:00	extension
P5	2	00:00	extension
P6	1	01:10	after conversion to <code>String</code>
P7	1	00:13	checked contents manually using method <code>#contents</code>
P8	1	00:51	after conversion to <code>String</code>
P9	2	00:00	extension
P10	2	00:00	extension

## RQ2. Usage of domain-specific information

	Group 1	Group 2	Used extension
Announcements	06:59	07:28	1/5
Stream	00:56	00:00	5/5

Domain-specific information can improve efficiency in debugging

## *RQ3.* Usage of debugging extensions

Developers use only familiar extensions;  
ignore new/unknown extensions

→ Encourage to use new extensions

# Improvement Opportunities: Highlight Extensions

TestFailure: Got nil instead of 42.

Stack

- GLMPharoScriptPresentation(GLMLoggedObject) announce:
- GLMPharoScriptPresentation(GLMRubricSmalltalkCode) evaluateSelectionAndDo:
- GTPlaygroundBasicTest testExecutionWithComment
- GTPlaygroundBasicTest(TestCase) performTest
- GTPlaygroundBasicTest(TestCase) runCase [ self setUp. se

Source All subscriptions Active subscriptions

```
announce: anAnnouncement
self logger logAnnouncement: anAnnouncement from: self.
super announce: anAnnouncement
```

Inspector

Variables

Type	Variable	Value
implicit	self	a GLMPharoScriptPresenta...a GLMPane(401197312 1))
attribute	acceptsSelection	nil
attribute	actions	an OrderedCollection(a G...ction a GLMPopupAction)
parameter	anAnnouncement	a GLMEvaluateSelection

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TestFailure: Got nil instead of 42. Bytecode ▾

Stack

- GLMPharoScriptPresentation(GLMLoggedObject) announce:
- GLMPharoScriptPresentation(GLMRubricSmalltalkCode) evaluateSelectionAndDo:
- GTPlaygroundBasicTest testExecutionWithComment
- GTPlaygroundBasicTest(TestCase) performTest
- GTPlaygroundBasicTest(TestCase) runCase [ self setUp. self performTest ]

Source All subscriptions Active subscriptions Where is? Browse

```
announce: anAnnouncement
self logger logAnnouncement: anAnnouncement from: self.
super announce: anAnnouncement
```

Inspector

Variables

Type	Variable	Value
implicit	self	a GLMPharoScriptPresenta...a GLMPane(401197312 1))
attribute	acceptsSelection	nil
attribute	actions	an OrderedCollection(a G...ction a GLMPopupAction)
parameter	anAnnouncement	a GLMEvaluateSelection

50 / 54

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# Improvement Opportunities: Domain-specific actions & Graphical Components

The screenshot shows the Smalltalk IDE interface. At the top, the window title is "Halt". The "Stack" panel is active, showing a list of frames. A red circle with the number "1" is placed over the "Step to selection change" button. The stack frames are:

- SubSmalltalkEditor evaluateSelectionAndDo: (highlighted)
- GLMMorphicPharoScriptRenderer(GLMMorphicPharoCc actOnEvaluateSelection:
- MessageSend value:
- MessageSend cull:

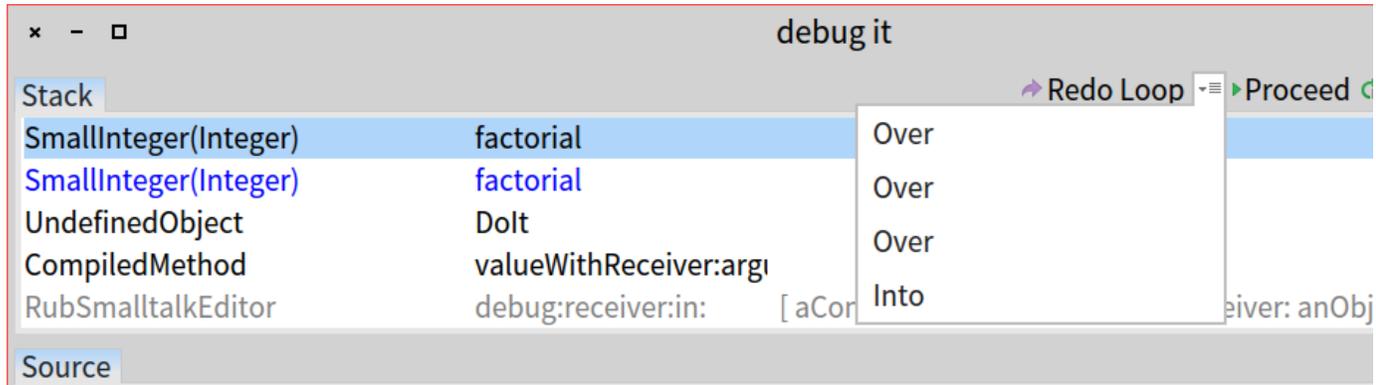
The "Source" panel is active, showing the source code for `evaluateSelectionAndDo: aBlock`. A red circle with the number "2" is placed over the "Morph" button in the Inspector panel. The source code is:

```
evaluateSelectionAndDo: aBlock
    "Treat the current selection as an expression; evaluate it and invoke aBlock
    with the result.
    If no selection is present select the current line."

    self lineSelectAndEmptyCheck: [^ ''].
    ^ self
      evaluate: self selectionForDoitAsStream
      andDo: aBlock
```

The Inspector panel shows the expression `40+2` with the value `"compute 42"`.

# Improvement Opportunities: Repetitive actions



debug it

Stack

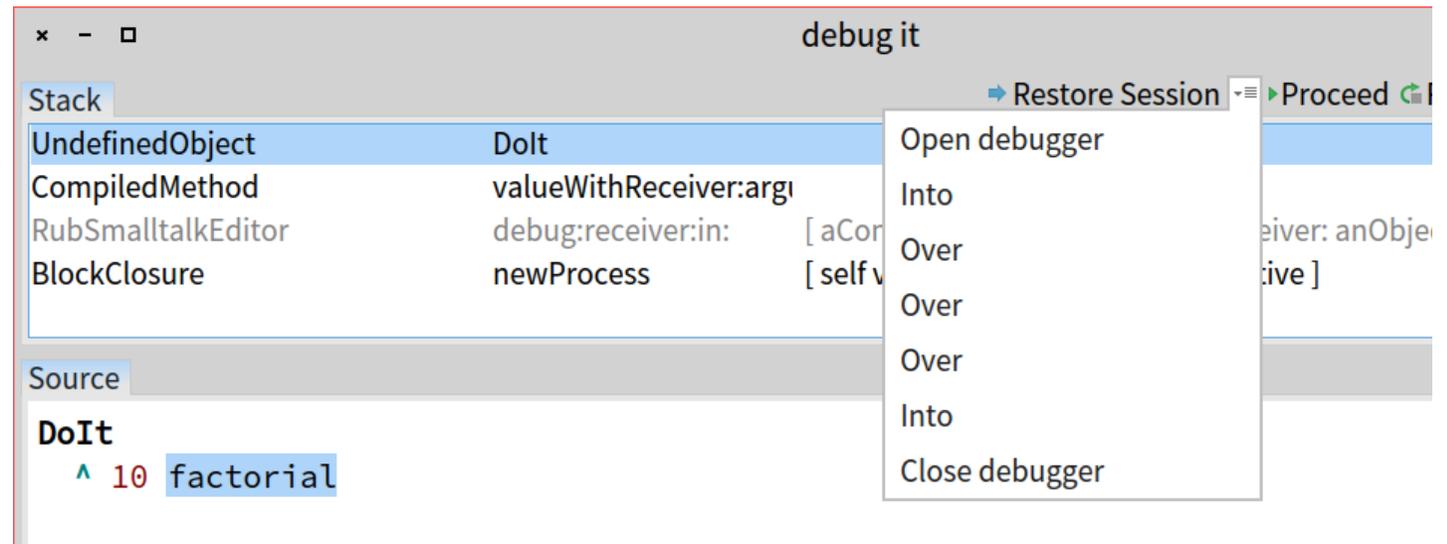
SmallInteger(Integer)	factorial	Over
SmallInteger(Integer)	factorial	Over
UndefinedObject	Dolt	Over
CompiledMethod	valueWithReceiver:arg	Into
RubSmalltalkEditor	debug:receiver:in: [ aCor	

Source

## factorial

"Answer the factorial of the receiver."

```
self = 0 ifTrue: [^ 1].  
self > 0 ifTrue: [^ self * (self - 1) factorial].  
self error: 'Not valid for negative integers'
```



debug it

Stack

UndefinedObject	Dolt	Open debugger
CompiledMethod	valueWithReceiver:arg	Into
RubSmalltalkEditor	debug:receiver:in: [ aCor	Over
BlockClosure	newProcess [ self v	Over

Source

DoIt

```
^ 10 factorial
```

# Debugging is difficult



# Experiment



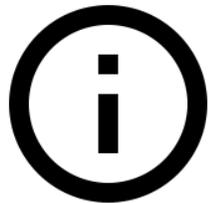
```
Stack
SmallInteger /
UndefinedObject Dot
TopicCompiler evaluate
PubSmalltalkEditor evaluateAndDo:
PubSmalltalkEditor evaluateAndDo:
PubSmalltalkEditor highlightEvaluationDo:
GLMPharoScriptPresenter/GLMPharoScriptPresenter evaluateEvaluationDo: [testMorph testView editor highlightEvaluationDo: anAction testMorph showStyle: testMorph]

Source
/ #number
"primitive. This primitive (for /) divides the receiver by the argument
and returns the result if the division is exact. Fail if the result is not a
whole Integer. Fail if the argument is 0 or is not a SmallInteger. Optional.
No lookup. See Object documentation whatIsPrimitive."

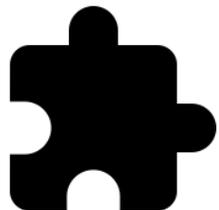
primitive: 180
#number isZero ifTrue: [(ZeroDivide divide: self) signal].
^((#number isMemberOf: SmallInteger)
  ifTrue: [(Fraction numerator: self denominator: aNumber) reduced]
  ifFalse: [super / aNumber])

Variables
Type Variable Value
self self 1
aNumber aNumber 0
thisContext thisContext SmallInteger
stackTop stackTop 0
```

# Results



Domain-specific information can be useful



New extensions often ignored

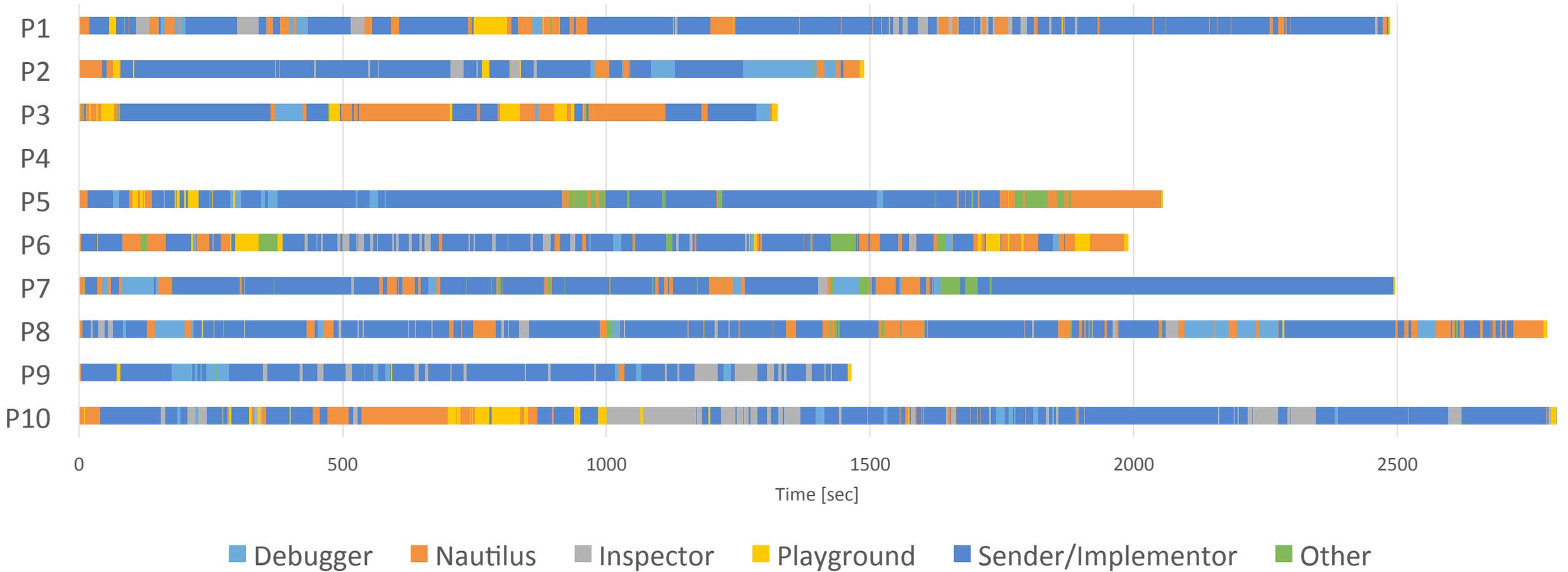
# Improvement Opportunities

```
Stack
GLMPharoScriptPresentation/GLMLoggedObject announce:
GLMPharoScriptPresentation/GLMRubricSmalltalkCode evaluateSelectionAndDo:
GTPlaygroundBasicTest testExecutionWithComment
GTPlaygroundBasicTest(TestCase) performTest
GTPlaygroundBasicTest(TestCase) runCase [self setUp. self performTest]

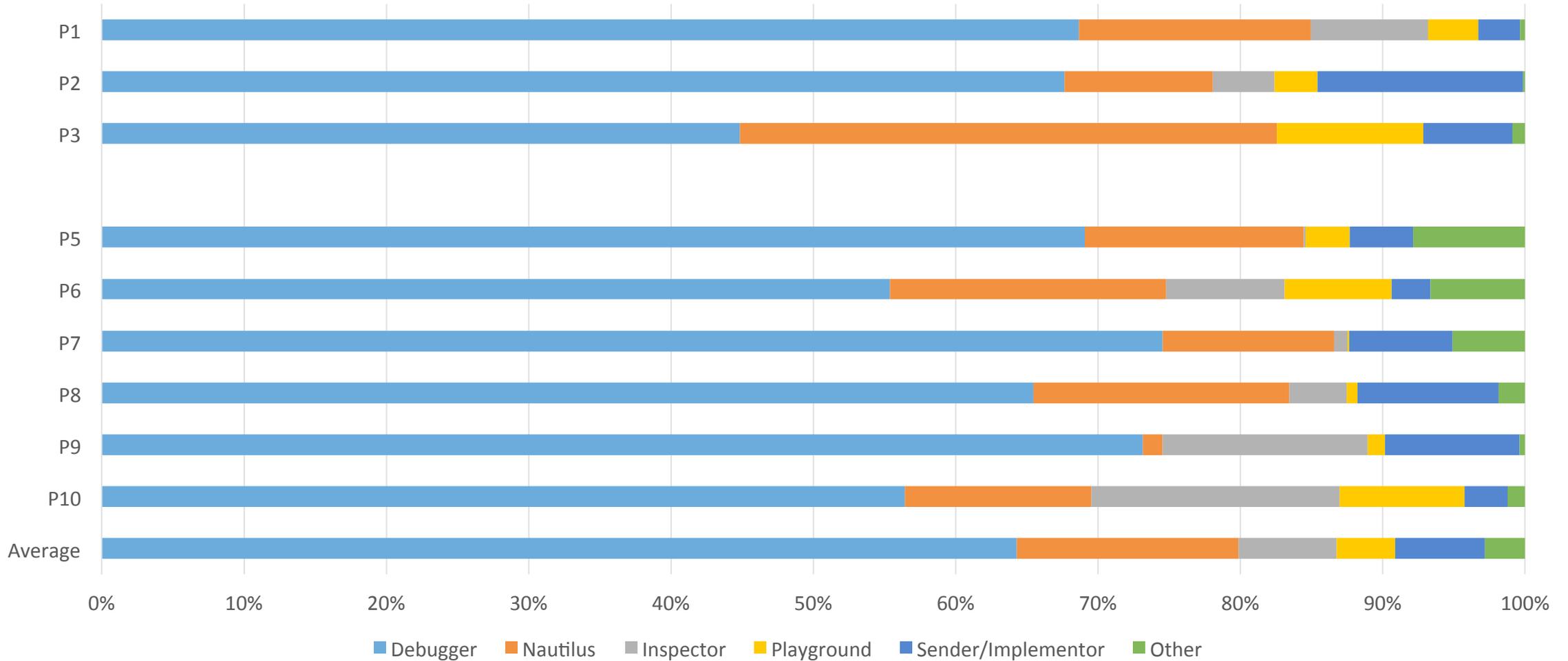
Source
announce: anAnnouncement
self logger logAnnouncement: anAnnouncement from: self.
super announce: anAnnouncement

Inspector
Variables
Type Variable Value
implicit self a GLMPharoScriptPresenta...a GLMPane(401197312 1))
attribute acceptsSelection nil
attribute actions an OrderedCollection[a G...ction a GLMPopupAction)
parameter anAnnouncement a GLMEvaluateSelection
```

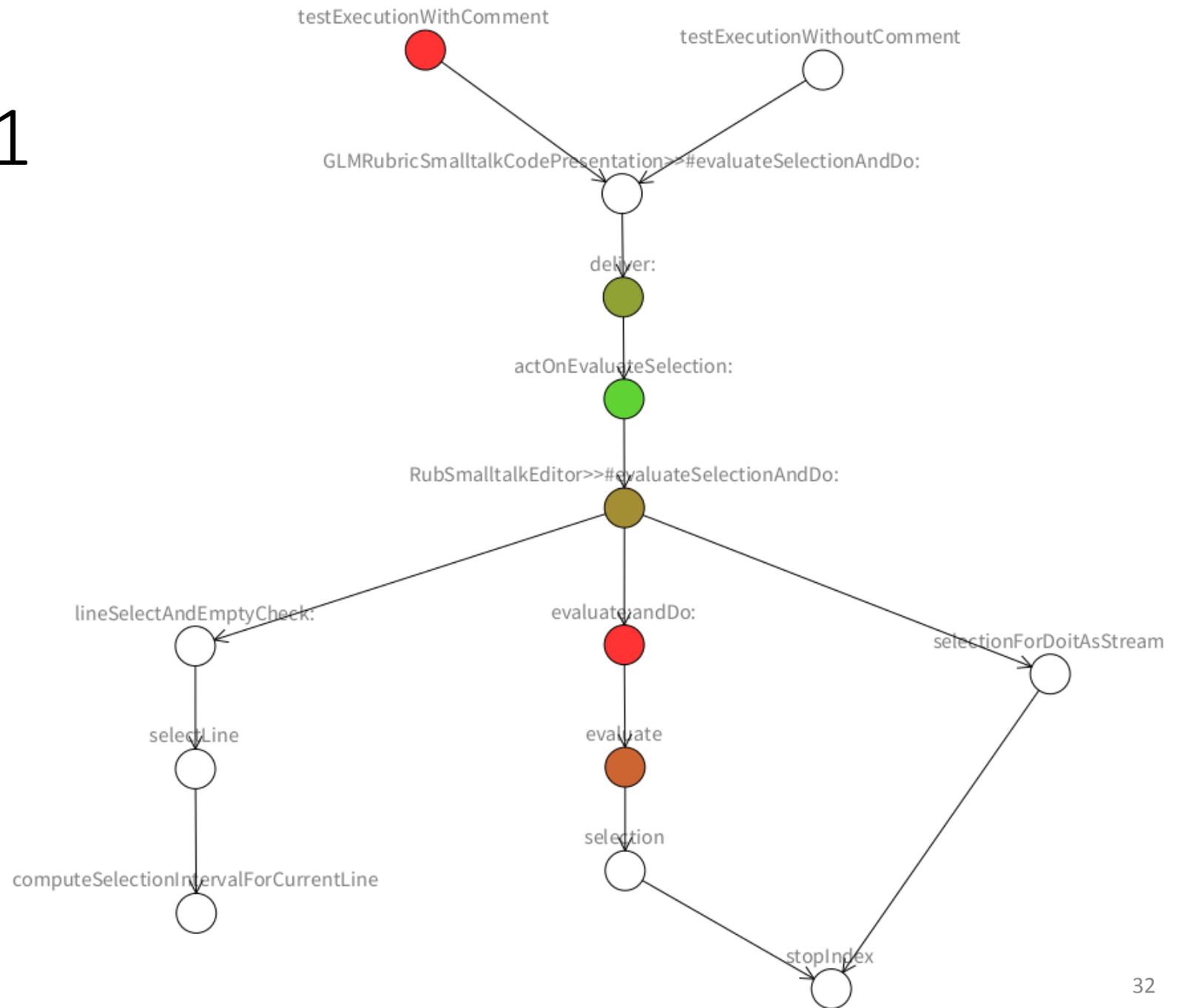
# Tool Usage Timeline



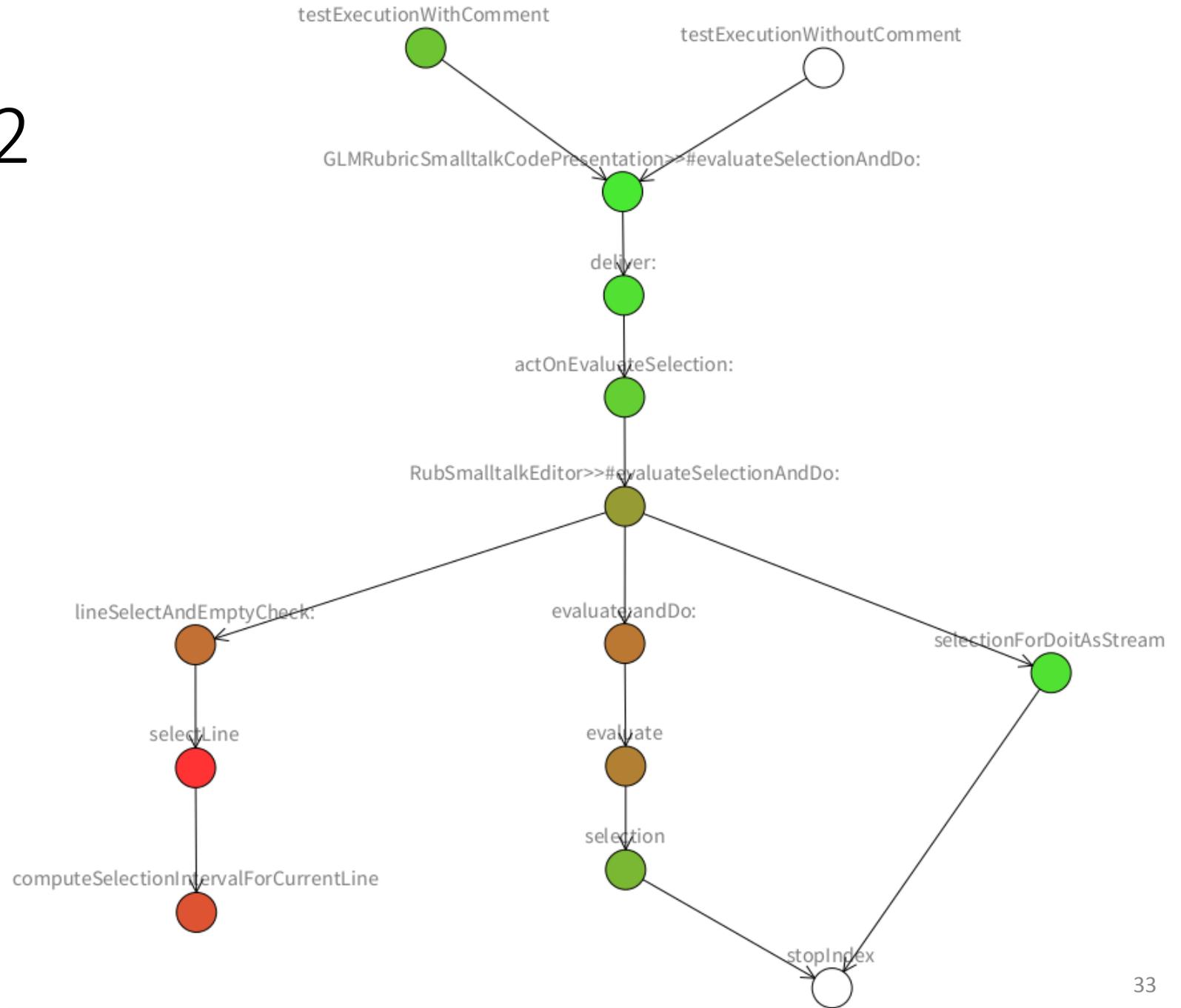
# Tool Usage



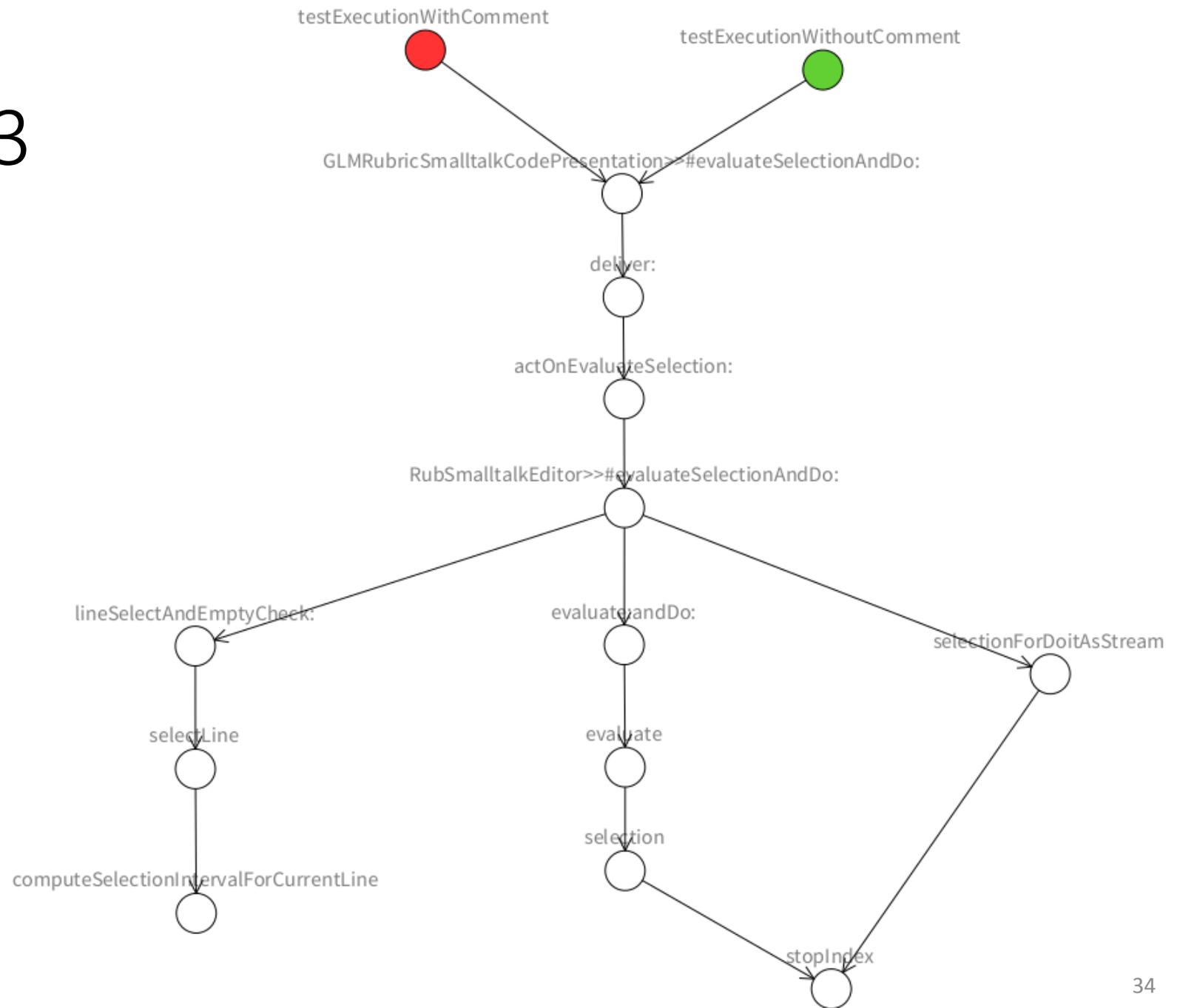
# Navigation P1



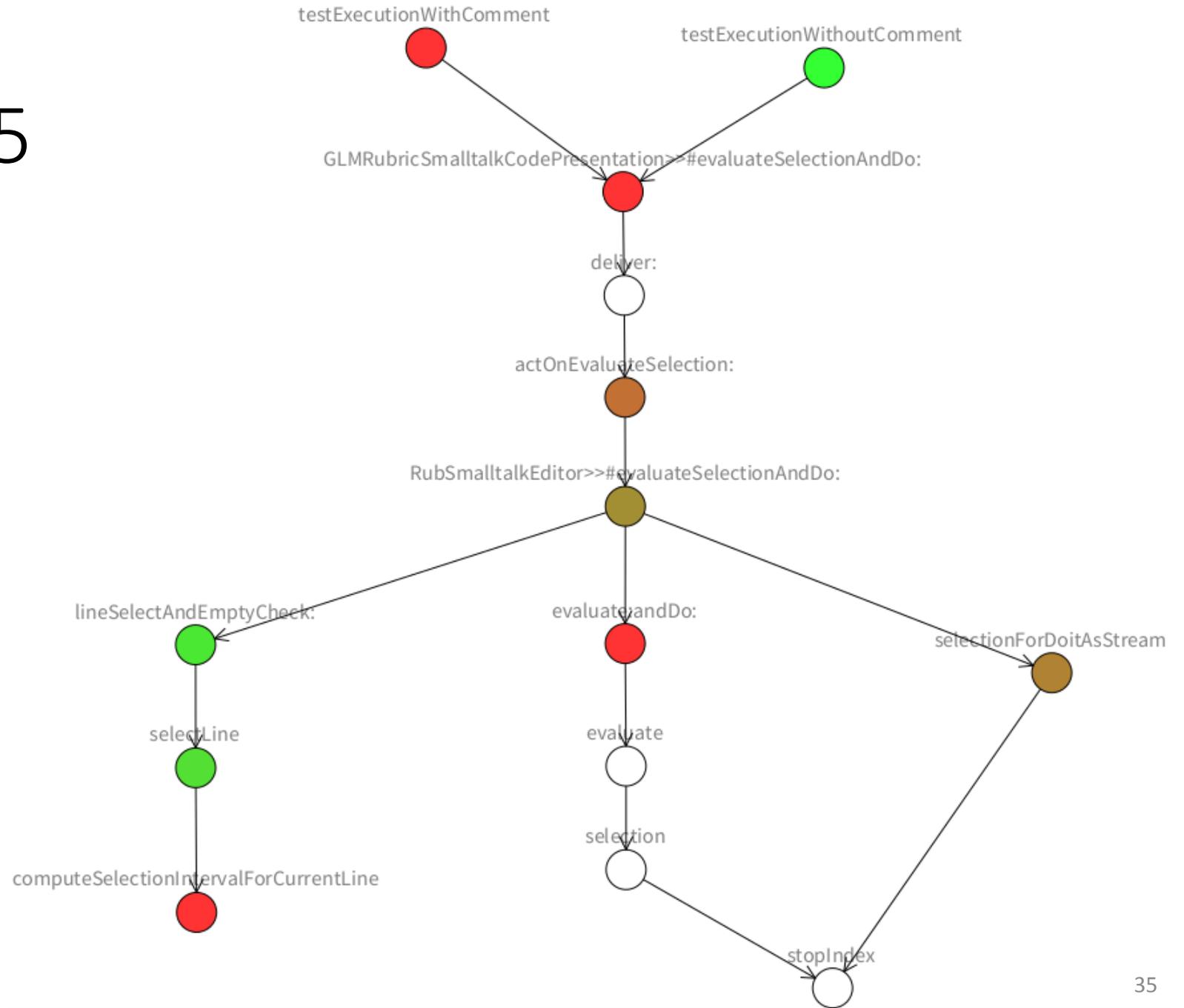
# Navigation P2



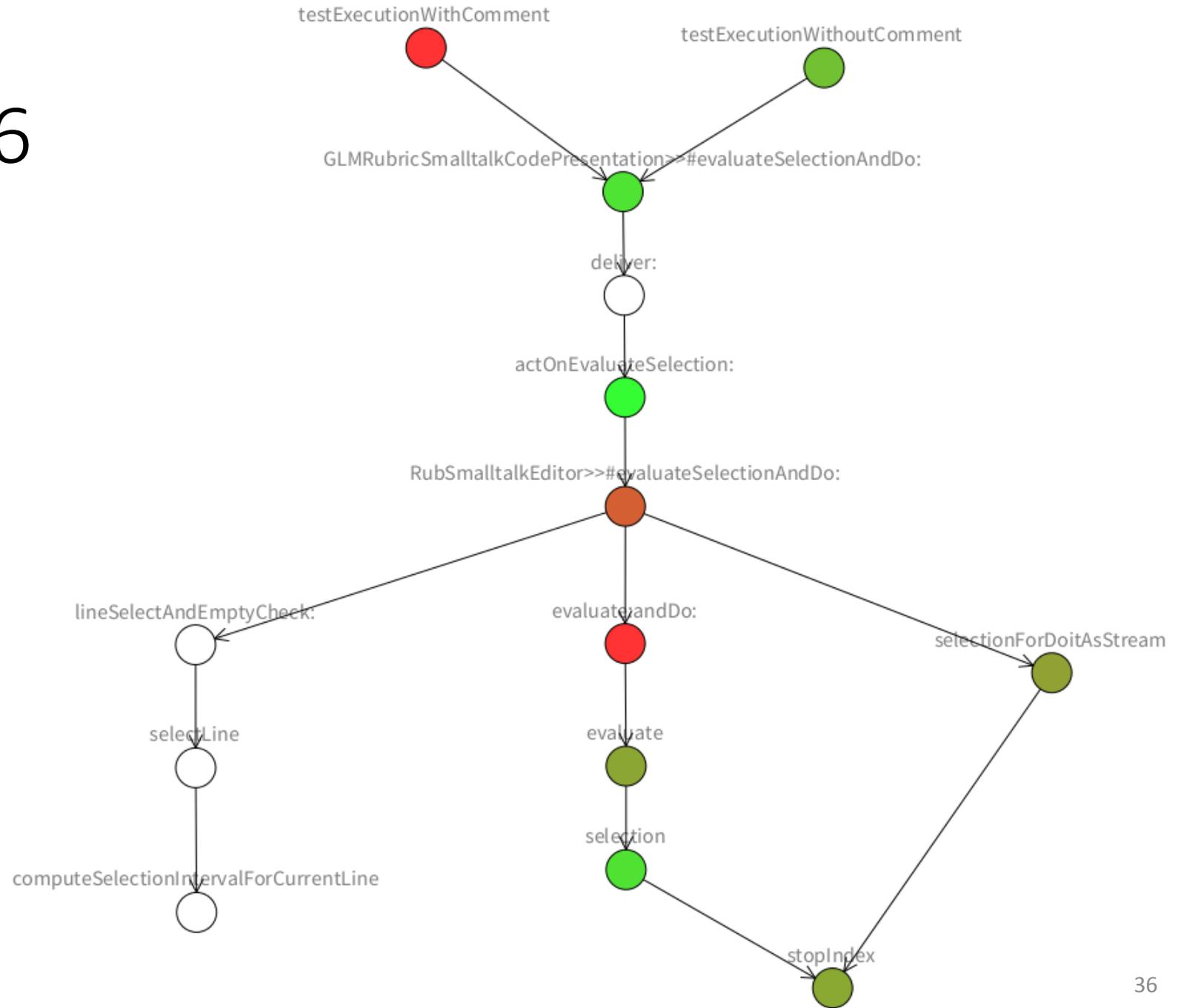
# Navigation P3



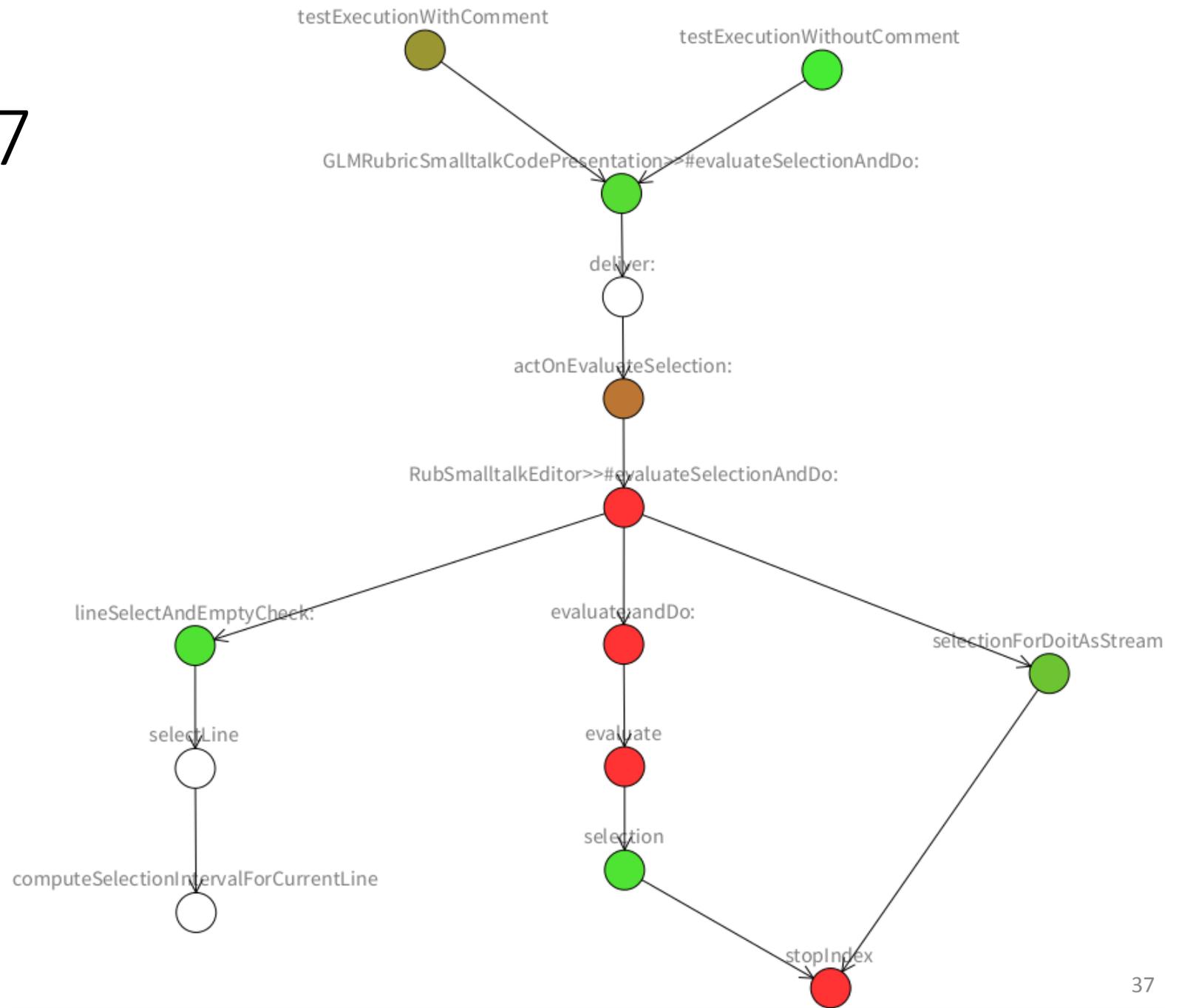
# Navigation P5



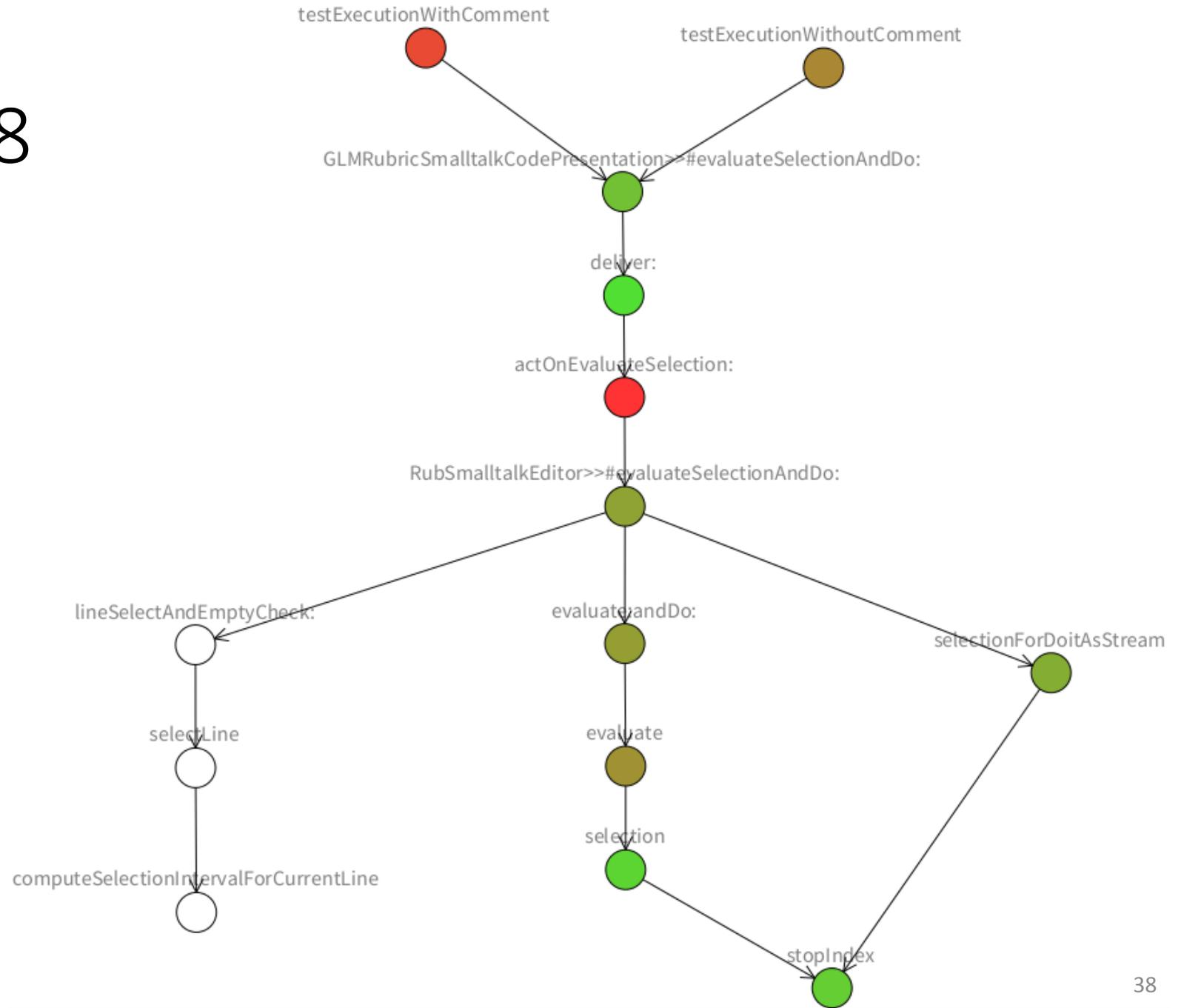
# Navigation P6



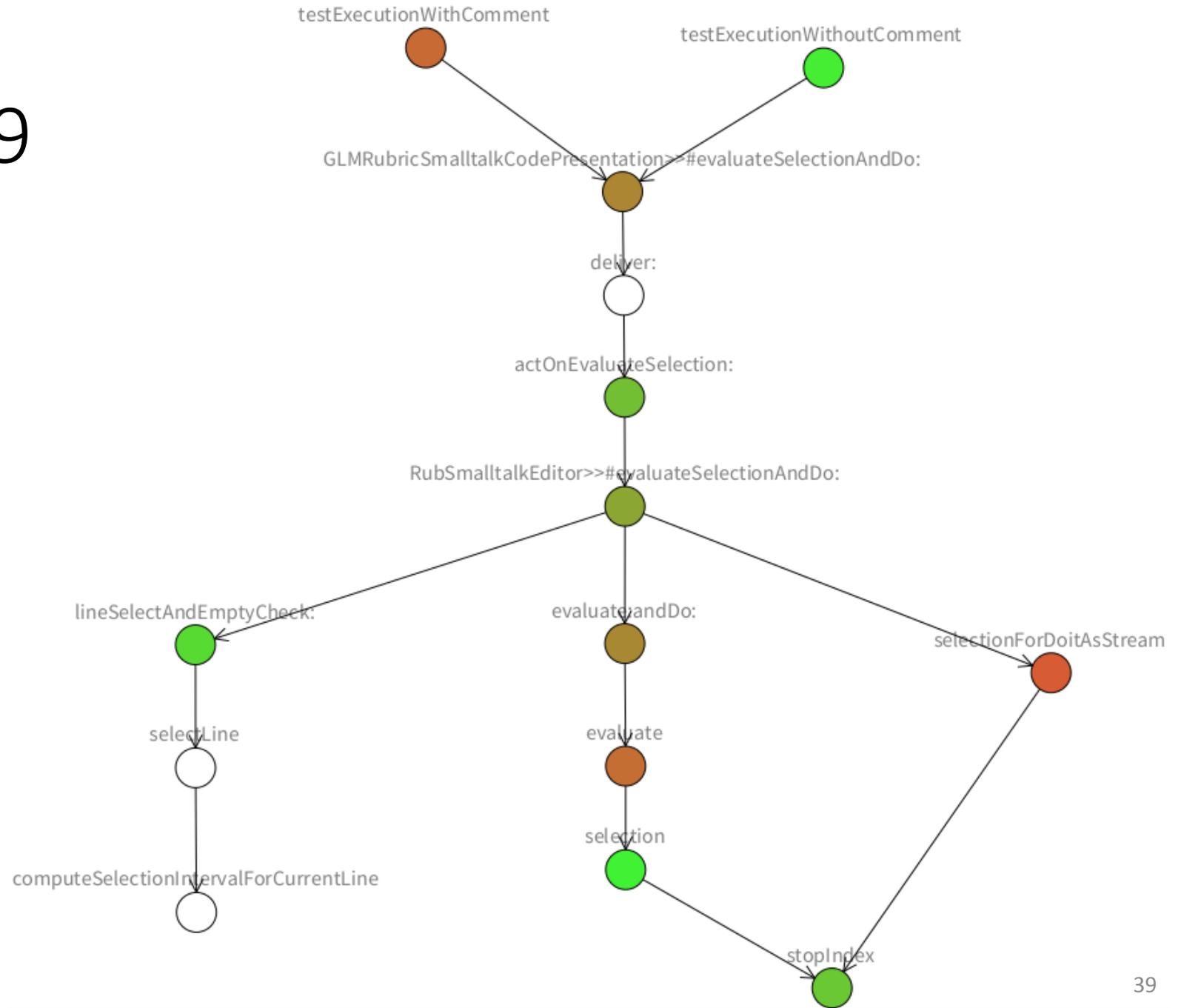
# Navigation P7



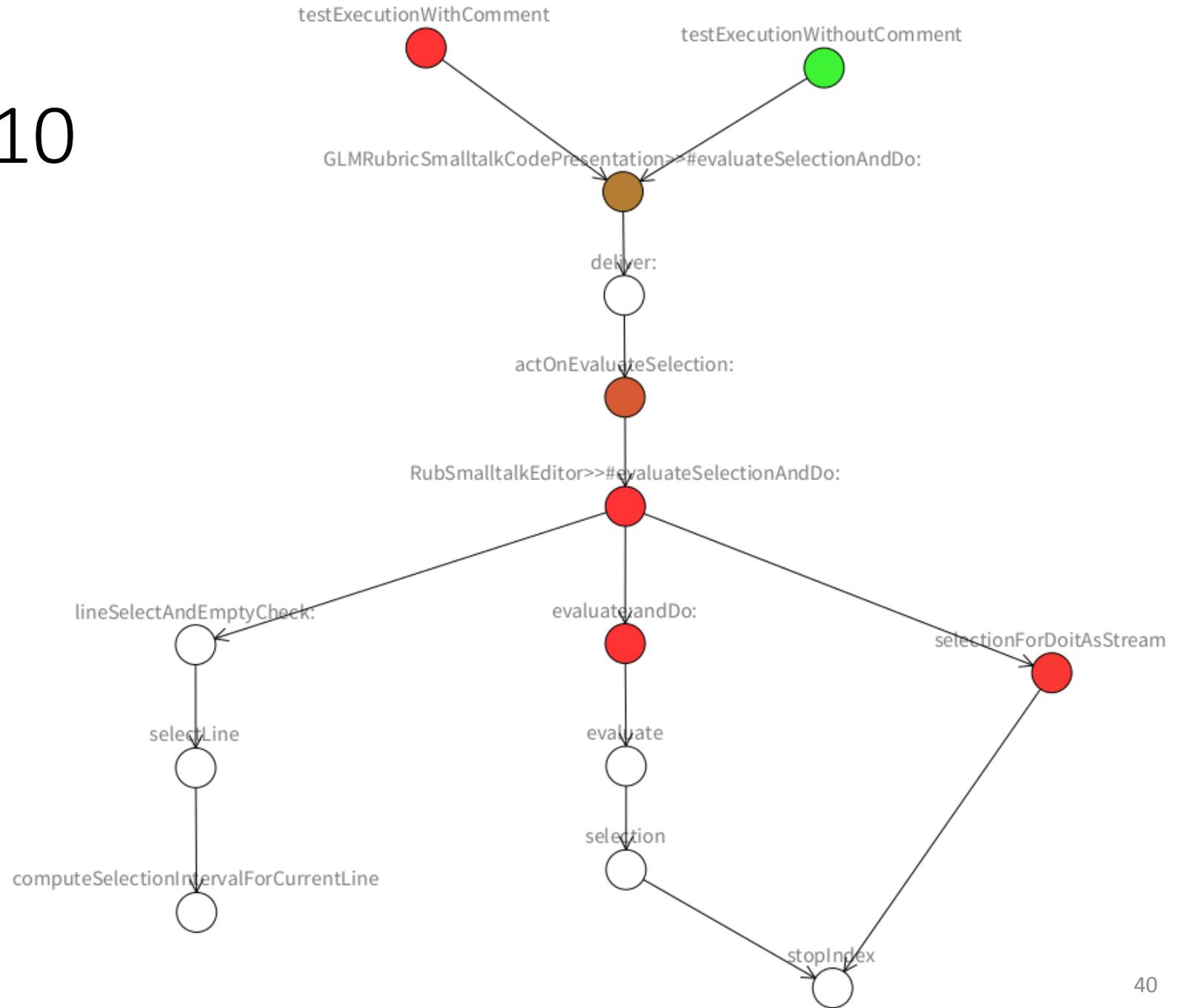
# Navigation P8



# Navigation P9



# Navigation P10



# Improvement Opportunities: Highlight Extensions

```
GTPlaygroundBasicTest(TestCase) performTest  
GTPlaygroundBasicTest(TestCase) runCase [ self setUp. self performTest ]
```

Source All subscriptions Active subscriptions Where is? Browse

```
announce: anAnnouncement  
self logger logAnnouncement: anAnnouncement from: self.  
super announce: anAnnouncement
```

```
GTPlaygroundBasicTest(TestCase) performTest  
GTPlaygroundBasicTest(TestCase) runCase [ self setUp. self performTest ]
```

Source All subscriptions Active subscriptions Where is? Browse

```
announce: anAnnouncement  
self logger logAnnouncement: anAnnouncement from: self.  
super announce: anAnnouncement
```

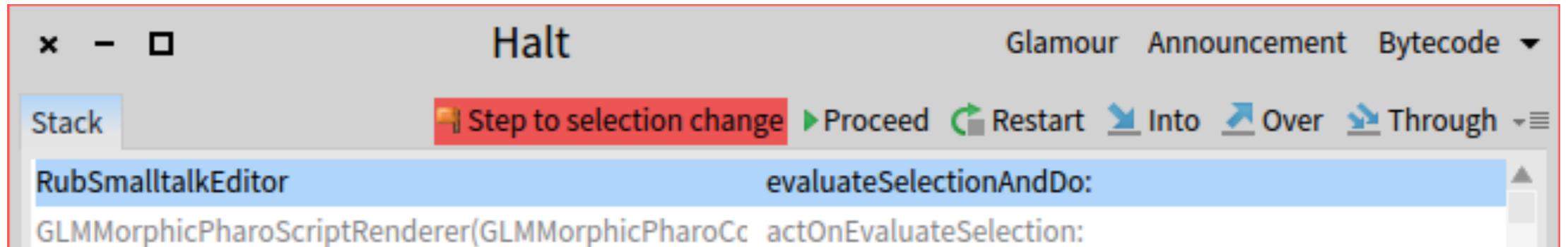
# Improvement Opportunities: Graphical Components

```
self lineSelectAndEmptyCheck: [^ ''].  
^ self  
  evaluate: self selectionForDoitAsStream  
  andDo: aBlock
```

Inspector Morph

```
.40+2 "compute 42"
```

# Improvement Opportunities: Domain-specific actions



Demo